Exclusive Vector Mesons and DVCS at low $|t|$

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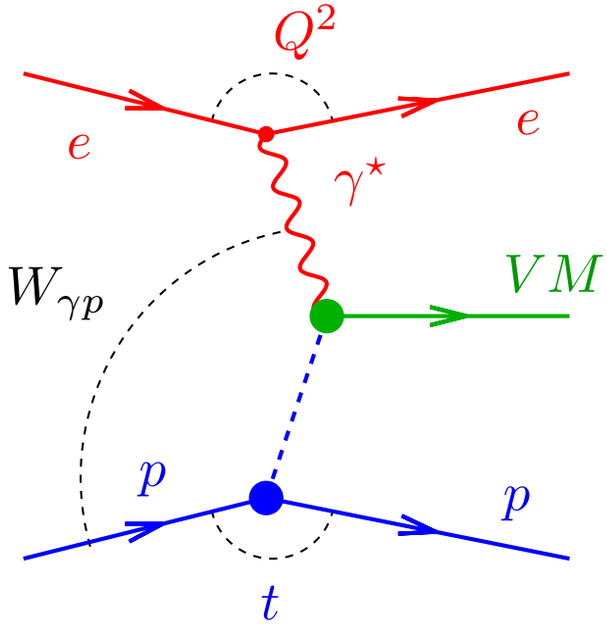
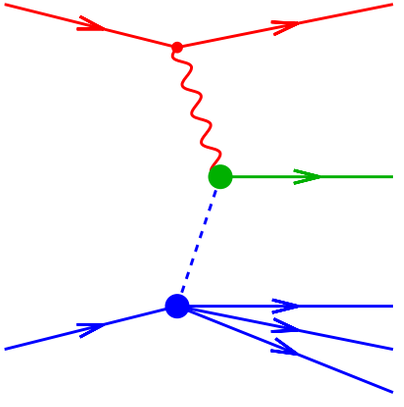
  - **cross section measurements from H1 and ZEUS**
  - **comparison with QCD models**
  - **beam-spin asymmetry measurements from HERMES**

Elastic Vector Meson Production at HERA

$$ep \longrightarrow e\,\mathrm{VM}\,p$$

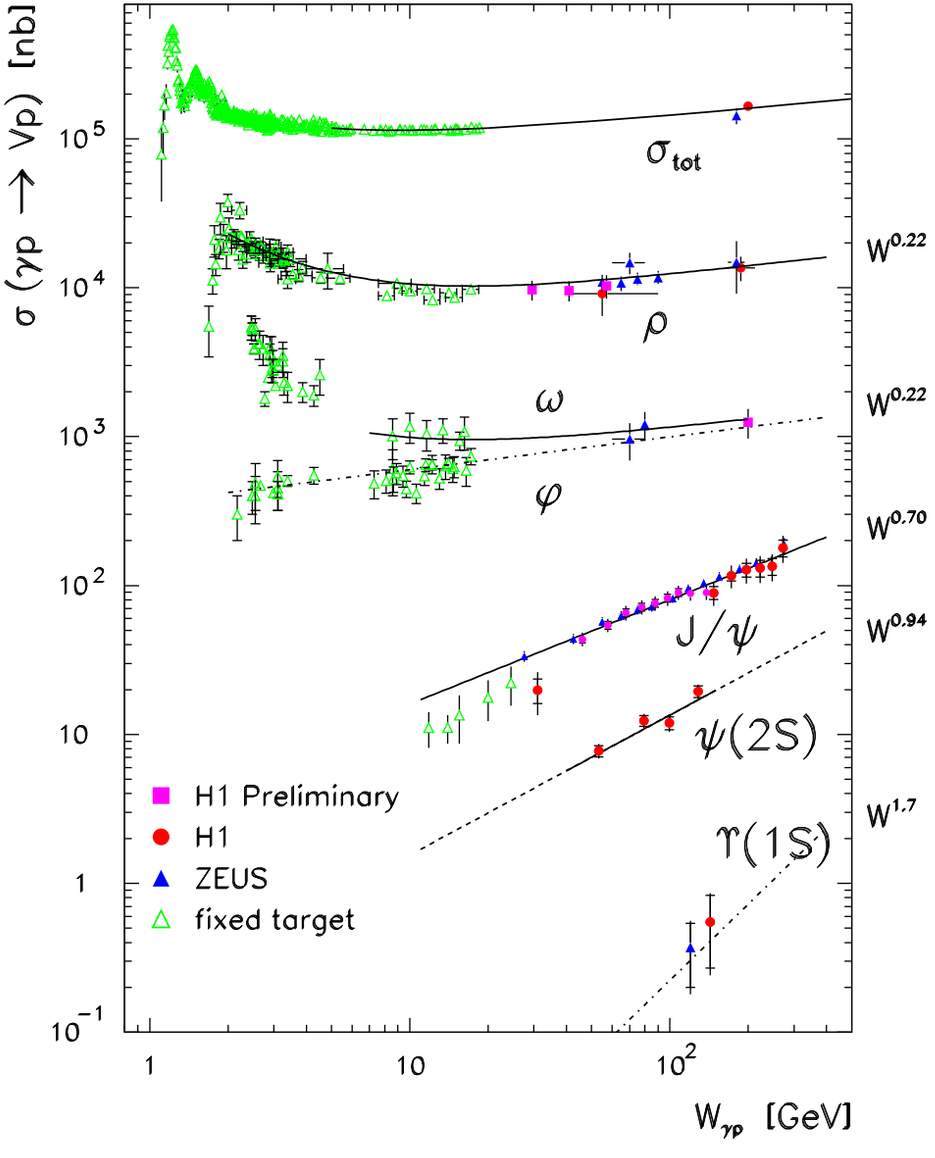


main background:

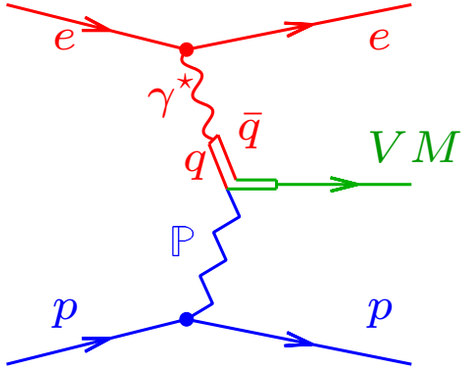


Q^2	γ^* virtuality	$0 < Q^2 < 100$ GeV^2
$W_{\gamma p}$	energy of γ^*p system	$20 < W_{\gamma p} < 290\,\mathrm{GeV}$
t	(4 mom. transfer)^2 at p vertex	$0 < \lvert t\rvert < 30\,\mathrm{GeV}^2$
VM	vector meson	$\rho^0,\ \omega,\ \phi,\ J/\psi,\ \Upsilon$

Elastic Photoproduction of Vector Mesons



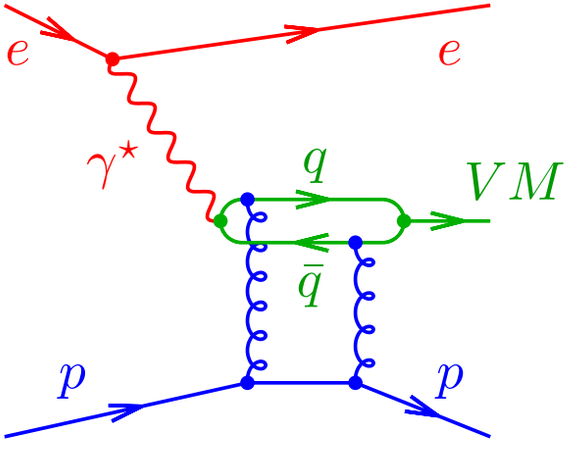
Soft Pomeron Model:



- exchange of a colourless object
  $\alpha_{\mathbb{P}}(t) = \alpha_0 + \alpha' \cdot t$
- $\sigma \propto W^{4(\alpha_{\mathbb{P}}(t)-1)} = W^{\delta} \approx W^{0.22}$

$\Rightarrow$ works for light VM
at $Q^2 \approx 0,\ t \approx 0$
$\Rightarrow$ steeper rise for heavy VM

Diffractive Vector Meson Production



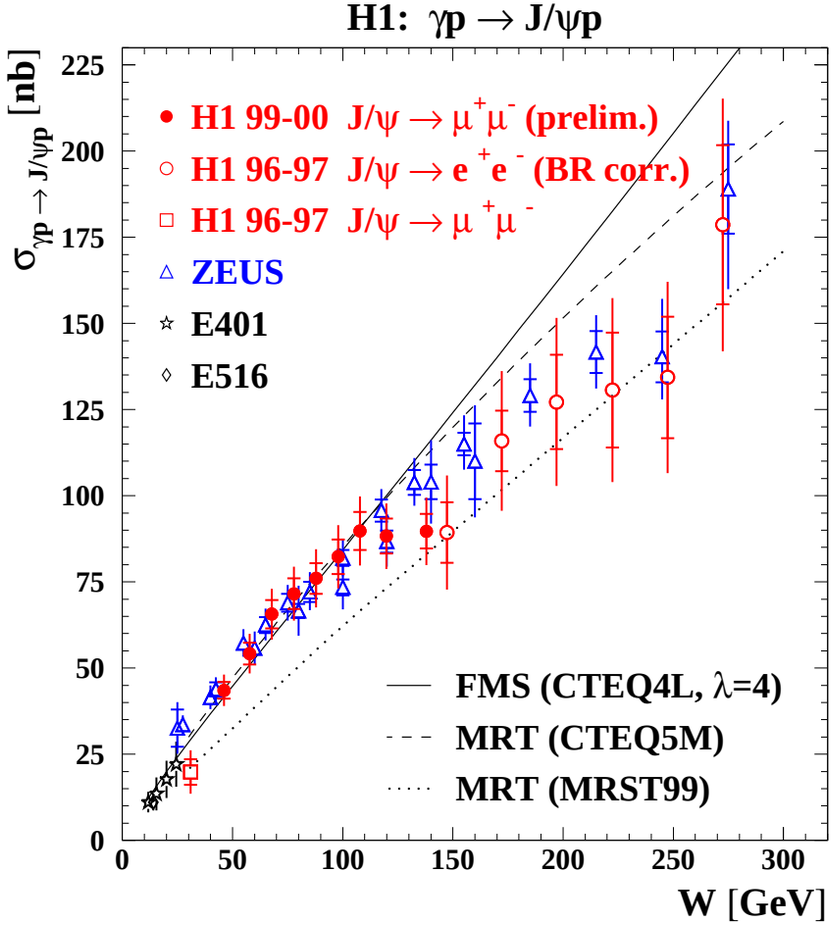
Perturbative QCD:

- exchange of 2 gluons / gluon ladder
- $\sigma \propto [x\ g(x, Q^2)]^2$

  $W^2 \propto \frac{1}{x}$ $\Rightarrow$ steep rise as a function of $\boldsymbol{W}$
- no or small $\boldsymbol{t}$ dependence of $\boldsymbol{\delta}$ expected
- unknown VM wave function

$\Rightarrow$ works in presence of hard scales ($\boldsymbol{M_q^2}$, $\boldsymbol{Q^2}$, $\boldsymbol{t}$)

J/ψ Photoproduction

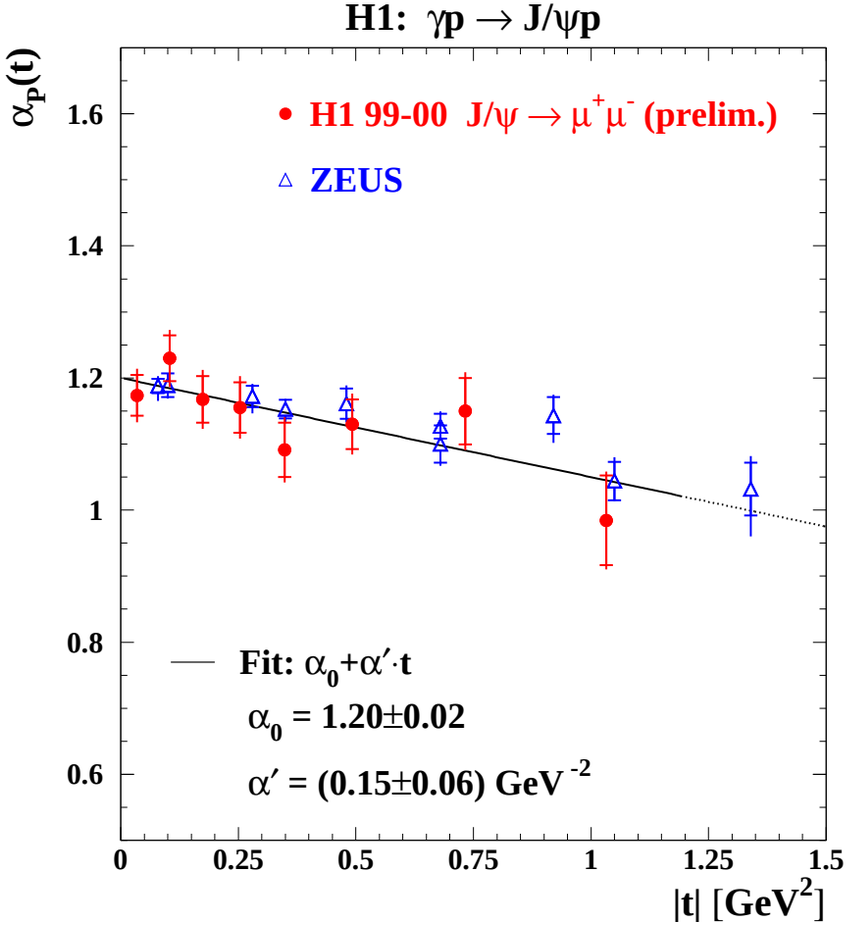


- Agreement between experiments
- QCD calculations qualitatively describe the rise

MRT: Martin, Ryskin, Teubner

FMS: Frankfurt, McDermott, Strikman

The Effective Pomeron Trajectory $\alpha_{\mathbb{P}}(t)$

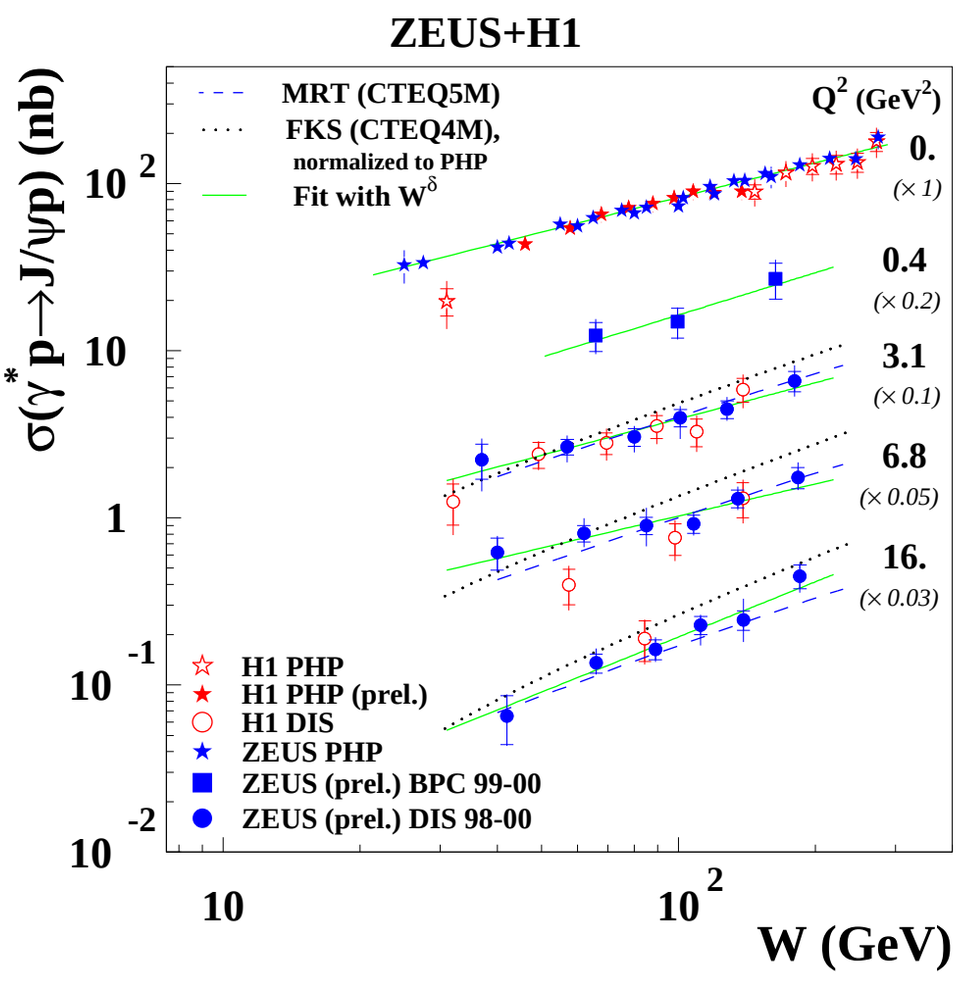


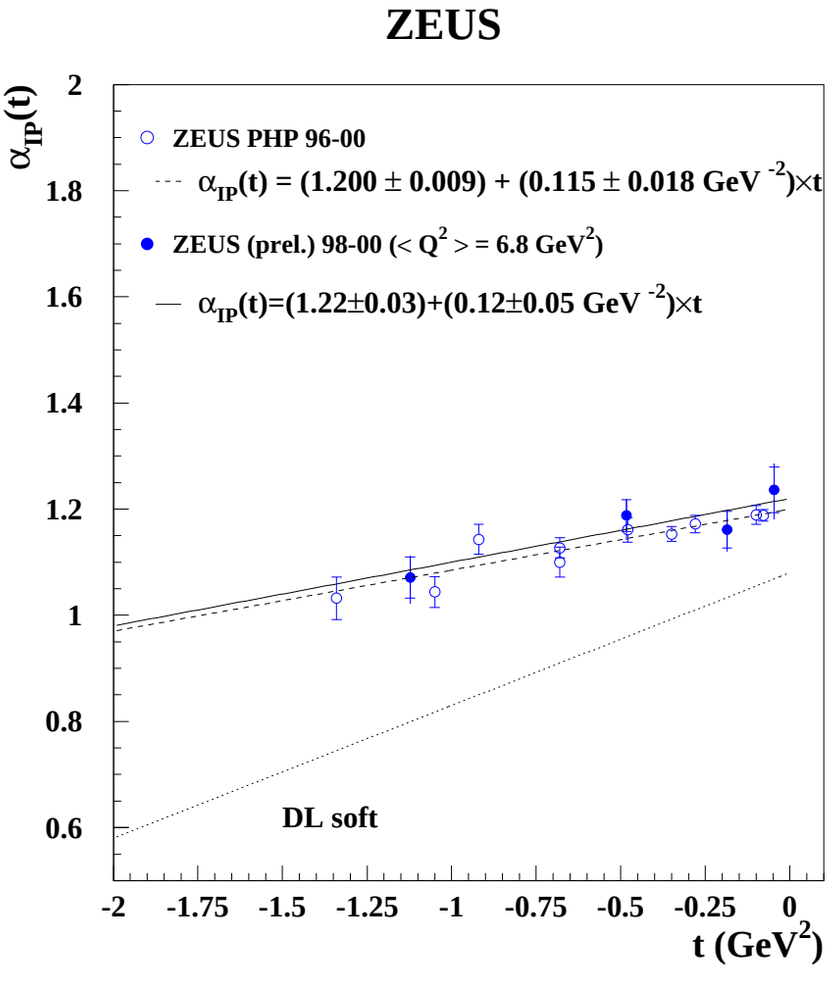
- measuring $\sigma(W)$ in bins of t
- fit $W^{\delta} = W^{4[\alpha_{\mathbb{P}}(t)-1]}$ gives effective Pomeron trajectory
- good agreement between H1 and ZEUS

$$\alpha'_{\mathrm{H1}} = 0.154 \pm 0.054 \pm 0.023$$
$$\alpha'_{\mathrm{ZEUS}} = 0.115 \pm 0.018^{+0.008}_{-0.015}$$
$$\alpha'_{\mathrm{soft}} = 0.25$$

$\Rightarrow$ **moderate shrinkage seen**

J/ψ Electroproduction

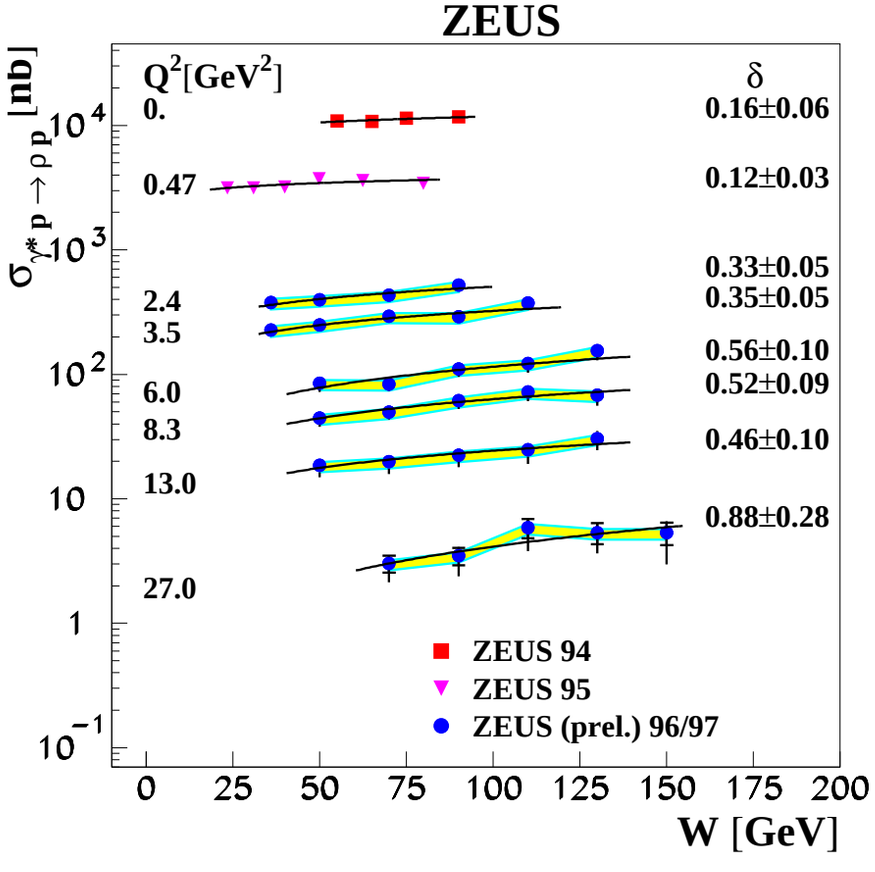


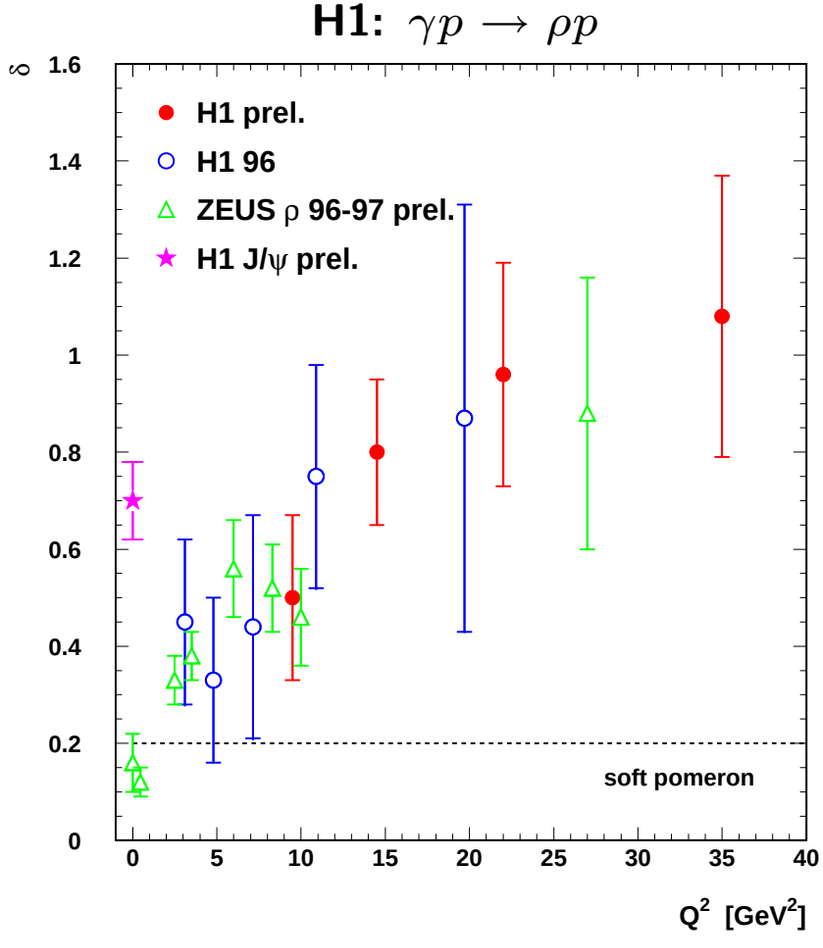


values of δ, α and α' compatible with photoproduction

consistent with pQCD expectation

ρ^0 Electroproduction





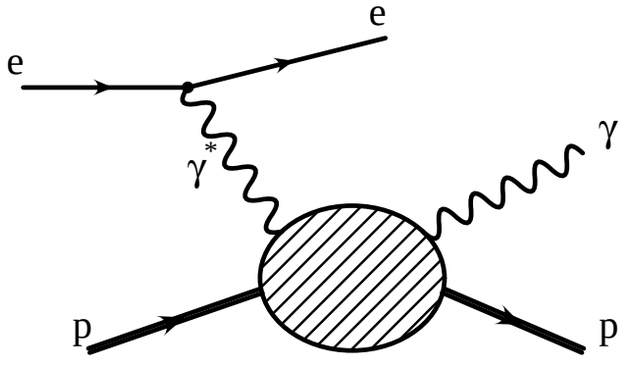
$\sigma_{\gamma^* p \to \rho p} \propto W^{\delta}$ at different Q^2 $\Rightarrow$ W rise gets steeper with Q^2

similar values as for J/ψ photoproduction $\Rightarrow$ high Q^2 possible hard scale

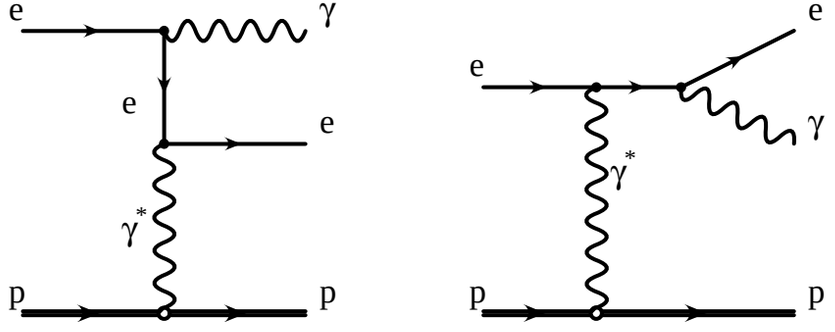
DVCS Introduction

$$e^+ + p \rightarrow e^+ + \gamma + p$$

DVCS



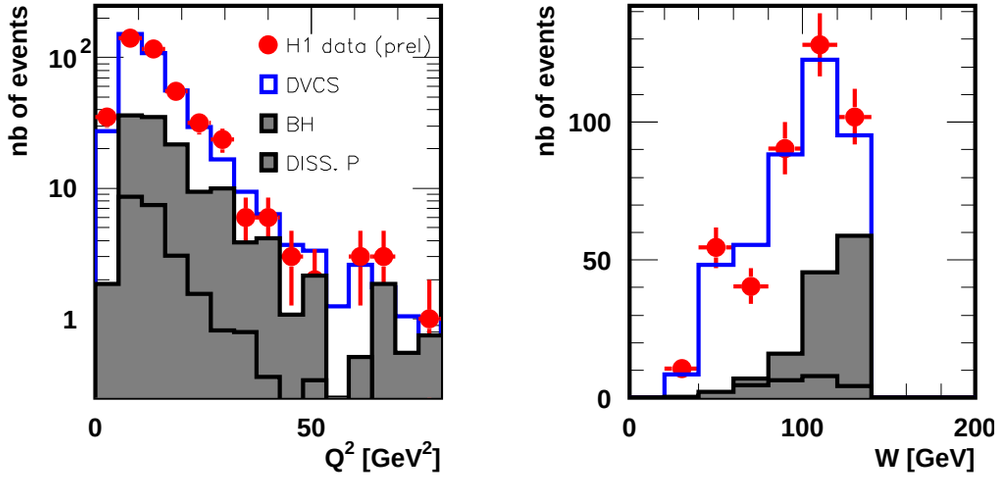
QED Background (Bethe-Heitler)



Why DVCS?

- no theoretical uncertainties associated with the wave function as in VM-production
- interplay between perturbative and non-perturbative QCD

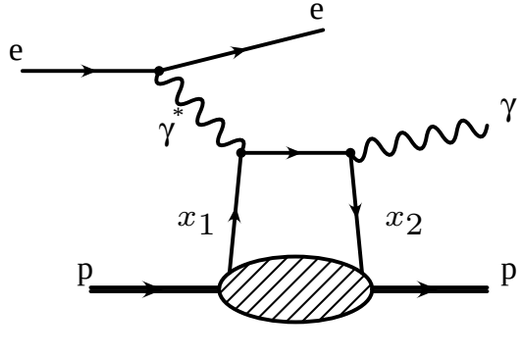
H1 preliminary



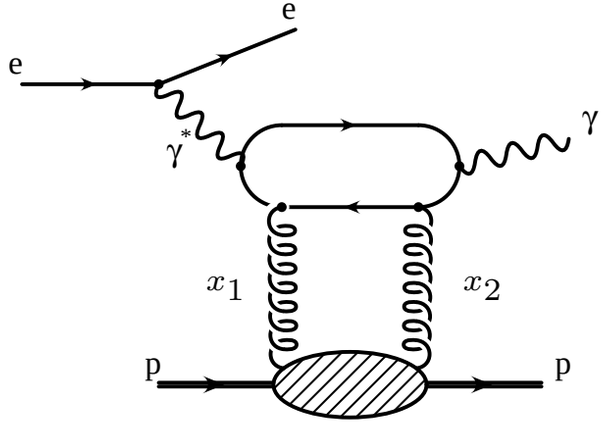
Models for DVCS

GPD-based Model $(x_1 \neq x_2)$

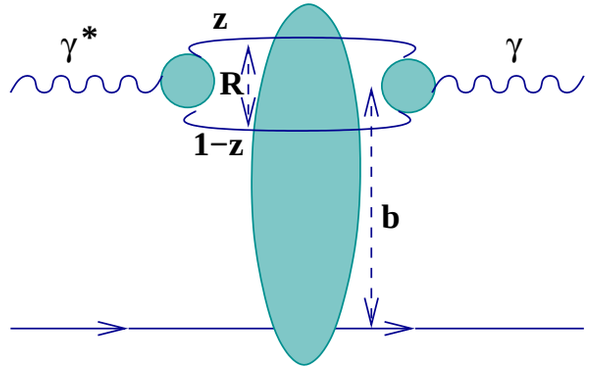
LO



NLO



Colour Dipole Model



$$A = \int dR^2 dz \psi_{in}^{\gamma^*} \sigma_{dipole} \psi_{out}^{\gamma}$$

different models for σ_{dipole}

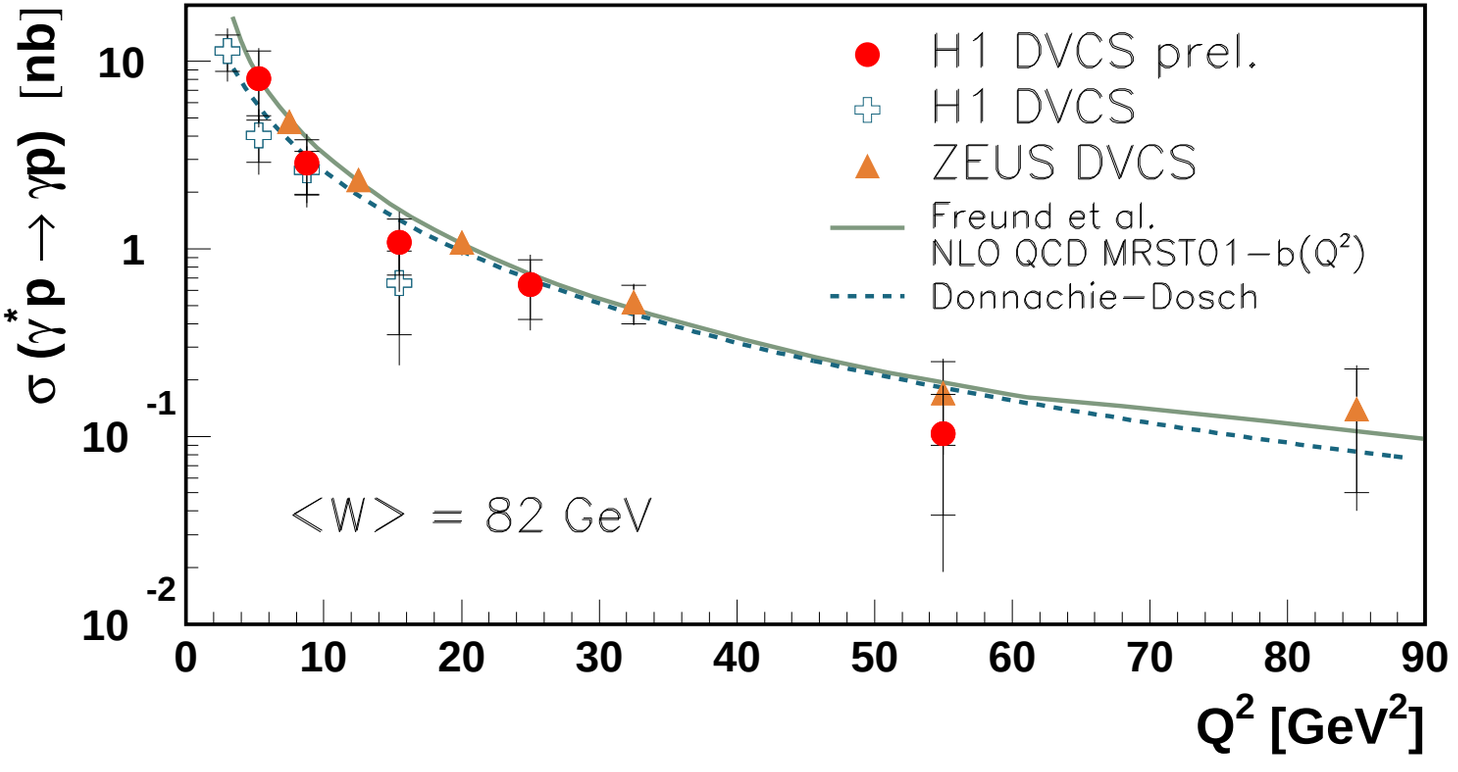
Frankfurt, Freund, Strikman Freund, McDermott

soft contribution: aligned jet model

Donnachie, Dosch

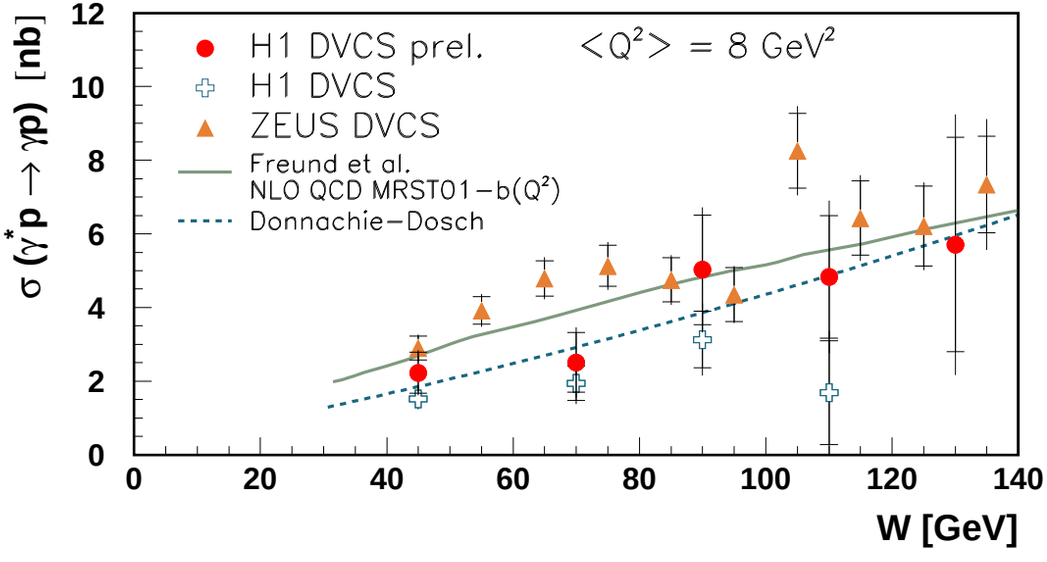
(soft + hard) pomeron exchange

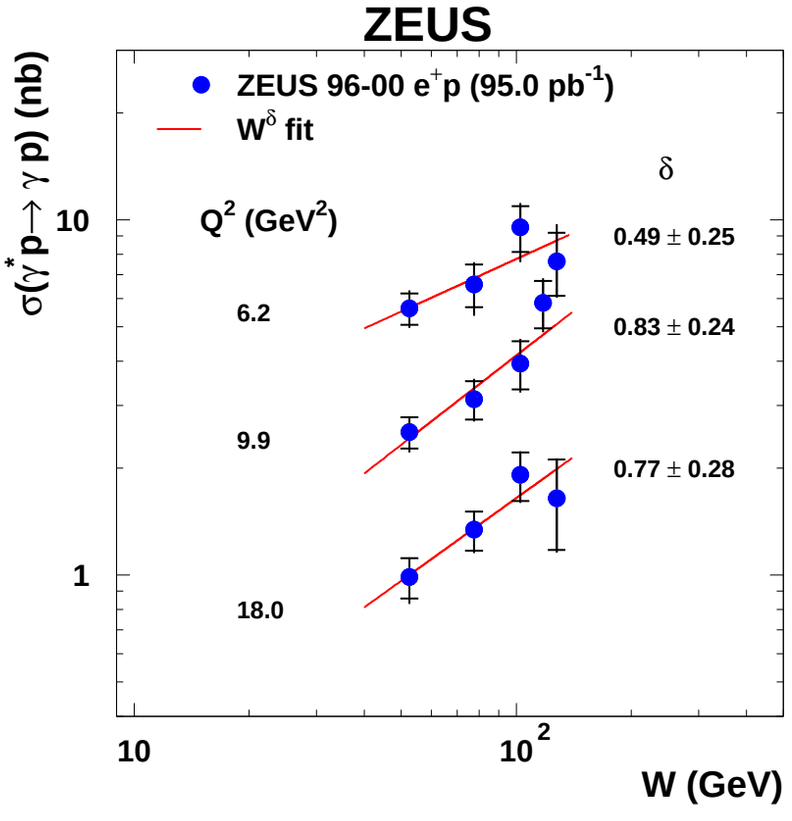
H1 & ZEUS: DVCS Results



- $\sigma(\gamma^* p \to \gamma p) \sim Q^{-3}$
- agreement between H1 and ZEUS
- both models in agreement with data

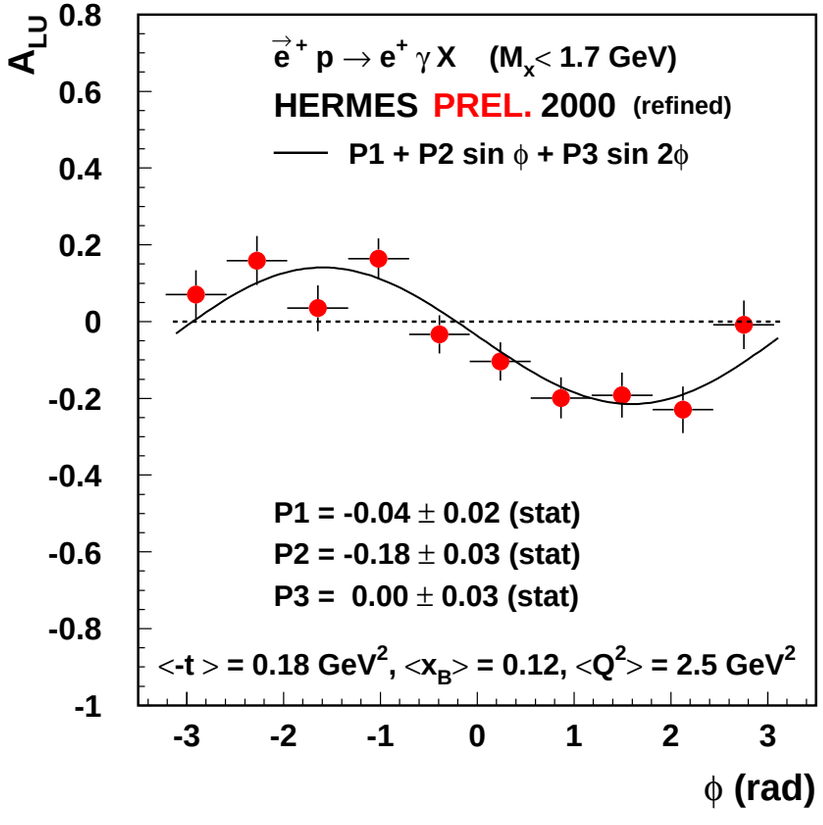
H1 & ZEUS: DVCS Results

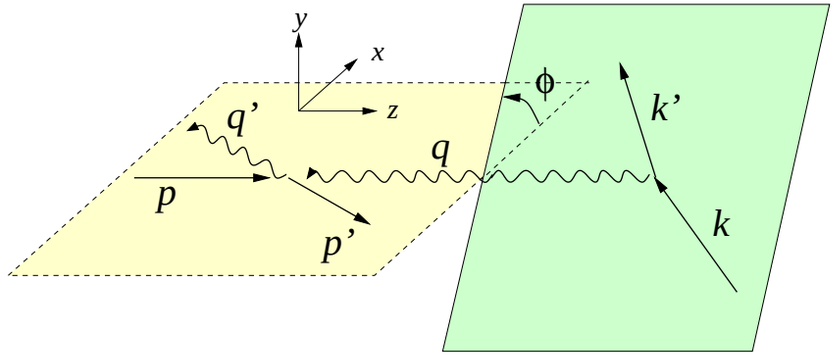




- similar rise as J/ψ in photoproduction
- both models in agreement with data

HERMES: Beam-Spin Azimuthal Asymmetry





Data 2000:

Longitudinally polarised positrons

Unpolarised hydrogen gas target

Interference between BH and DVCS

$$A_{\mathrm{LU}}(\phi) = \frac{N^+(\phi) - N^-(\phi)}{N^+(\phi) + N^-(\phi)}$$

LU **L**ongitudinally polarised beam/ **U**npolarised target

$N^{\pm}$ Number of events with corresponding beam helicity states

Conclusions

- **VM:**
  - high precision in large kinematic region
  - agreement between H1 and ZEUS
  - pQCD predictions in agreement with data for large M_q^2 and Q^2
  - ρ shows transition from soft to hard physics

- **DVCS:**
  - cross section measured at HERA I by H1 and ZEUS
  - $\sigma(\gamma^* p \rightarrow \gamma p)$ rises steeply with $W \Rightarrow$ hard process
  - agreement between H1 and ZEUS
  - GPD-based and Colour Dipole Models in agreement with data
  - beam-spin azimuthal asymmetry measured at HERA I by HERMES

  - looking forward to measure asymmetries at HERA II

Normalisation uncertainty